VI. *On the Diurnal Variation of the Magnetic Declination at St. Helena.*

By Lieut.-Colonel EDWARD SABINE, *R.A., For. Sec. R.S.*

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IT has long been known that in Europe the north end of a magnet suspended horizontally (meaning by the north end the end which is directed towards the north), moves to the *East* from the night until between 7 and 8 o'clock in the morning, when an opposite movement commences, and the north end of the magnet moves to the *West*. Recent observations have shown that a similar movement takes place at the same hours of local time in North America, and that it is general in the middle latitudes of the northern hemisphere.

It has also been known for some years past, and has been confirmed by recent observations, that in the middle latitudes of the southern hemisphere, the north end of the magnet moves in a contrary direction to that which has been described as taking place in the northern hemisphere, viz. that it moves to the west until 8 o'clock in the morning, or thereabouts, and then returns towards the east.

From the contrariety of the movement which is thus found to take place in the same meridians at the same hours in the opposite hemispheres, it seemed a not unreasonable conjecture, that at some intermediate point in each meridian, the causes, whatever they might be, which occasion these movements might counterbalance each other, and that the diurnal variation might consequently disappear: and questions were raised whether the line connecting these points in the different meridians would be found to coincide with the terrestrial equator, or with the line of no dip, or with one of the isodynamic lines.

The problem, which observation was thus called upon to resolve, has been stated with so much perspicuity by M. ARAGO in the Annuaire for 1836, that I may be permitted to reproduce it in his own words:—

"Dans l'hémisphère nord, la pointe d'une aiguille horizontale aimantée, qui se tourne vers le nord, marche, de l'est à l'ouest, depuis $8\frac{1}{4}^{h}$ du mat. jusqu'à $1\frac{1}{4}^{h}$ après midi; de l'ouest à l'est, depuis $1\frac{1}{4}^{h}$ après midi jusqu'au lendemain matin. Dans l'hémisphère sud, la pointe tournée vers le nord marche, de l'ouest à l'est, depuis $8\frac{1}{4}^{h}$ du matin jusqu'à $1\frac{1}{4}^{h}$ après midi; c'est précisement l'opposé du mouvement qu'effectue, aux mêmes heures, dans notre hémisphère, la même pointe nord.

"Supposons qu'un observateur partant de Paris s'avance vers l'équateur. Tant qu'il sera dans notre hémisphère, la pointe nord de son aiguille effectuera tous les matins un mouvement vers l'occident; dans l'hémisphère opposé, la pointe nord de cette

même aiguille éprouvera tous les matins un mouvement vers l'orient. Il est impossible que ce passage du mouvement occidental au mouvement oriental se fasse d'une manière brusque: il y a nécessairement entre la zone ou s'observe le premier de ces mouvements, et celle où s'opère le second, une ligne où, le matin, l'aiguille ne marche ni à l'orient ni à l'occident, c'est-à-dire reste stationnaire.

"Une semblable ligne ne peut pas manquer d'exister; mais où la trouver? Est-elle l'équateur magnétique, l'équateur terrestre, ou bien quelque courbe d'égale intensité?"

In the recent work of the Baron von HUMBOLDT (Cosmos, vol. i.), this question is also adverted to, and the problem is stated in nearly similar terms: after noticing the contrariety of movement in the two hemispheres, Baron von HUMBOLDT remarks that attention has been justly called to the belief "that there must be a region of the earth, probably between the terrestrial and magnetical equators, in which no horary variation of the declination is sensible. This fourth curve, which might be called the curve of no motion, or rather *the line of no horary variation of the declination*, has not yet been found."

In the choice of the stations at which the magnetical observatories established by the British Government and by the East India Company in 1840 were placed, the solution of this problem was not overlooked. SINGAPORE is situated close to the terrestrial equator; it was therefore well-suited to meet the suggestion of M. ARAGO in that respect: it is also not far distant from the line of no dip, and might be expected therefore to exhibit, in some degree at least, the peculiarities which might appertain to stations so circumstanced. In this country, a somewhat different mode of viewing the magnetic system of the globe from that which prevailed generally in France, caused an opinion to be entertained, that a different line from any of those suggested by M. ARAGO might not improbably prove the dividing line of the two magnetic hemispheres in this respect; and that the phenomena of the diurnal variation, whatever they may be, which should characterise the dividing line, might be most advantageously studied at a station chosen in its vicinity. The line here referred to passes round the globe, crossing the several meridian lines at points where the magnetic intensity in each is a minimum: or, it may be more precisely defined, as the locus of the points of minimum intensity of all lines on the surface of the earth drawn at right angles to itself. Its position has been traced through all the meridians of the globe with considerable approximation*. It is not by its definition necessarily an *isodynamic* line, or a line of equal magnetic force; and in fact, it is far from being so, the intensity of the force ranging in different parts of the line from 6·4 to 7·6 in absolute measure. It happens that Singapore, which, as already stated, is situated close to the terrestrial equator, and near the line of no dip, is in a part of the globe where the lines of least force and of no dip approach each other most nearly; consequently the observations at Singapore might be expected to exemplify the

* Reports of the British Association, 1837. Philosophical Magazine, vol. xiv. p. 81.

phenomena, whatever they might be, of an intermediate station, whether the intermediate character should be derived from proximity to the terrestrial equator, to the line of no dip, or to that of least force. St. HELENA is situated close to the line of least magnetic force in a quarter of the globe where that line departs most widely both from the terrestrial equator and from the line of no dip; its latitude being about $-16°$ and the dip about $-22°$. Should therefore the diurnal variation at St. Helena be found to possess the intermediate character, it was considered that it would go far to indicate that the character was given by proximity to the line of least intensity, rather than to either of the two other lines. A third station, the CAPE OF GOOD HOPE, seemed well-suited to subject this latter point to a still severer scrutiny; although somewhat more distant than St. Helena from the line of least intensity (which passes between those stations but nearer to St. Helena than to the Cape), the magnetic force at the Cape is still so weak as not to exceed in absolute measure the intensity on some parts of the line of least force (in the neighbourhood of Singapore for example): it was considered therefore as not improbable that if the intermediate character should prove to belong to stations at or near the line of least intensity, the Cape of Good Hope might be found to partake of the peculiarities of such a station, although the distance of the Cape from the terrestrial equator is not less than 34°, and the dip exceeds $-53°$.

From the moment when the observations of the first complete year at St. Helena and the Cape arrived in England and were examined, their bearing on the solution of the problem was perceived: but as opinions had been expressed of the probable influence of the cylindrical boxes in which the magnetometers were originally placed in generating currents of air at particular hours of the day and seasons of the year, and possibly of vitiating to a greater or less degree the diurnal variation thus observed, it was judged more prudent to suspend a notice of the inferences to which they led, until the observations of subsequent years made with additional precautions should have been received.

The results which will be now communicated to the Society, are founded on the observations at St. Helena of five years' continuance, viz. from 1841 to 1845 inclusive. From the beginning of 1841 to July 1843, the magnet was inclosed in a cylindrical box, corresponding to the description in page 14 of the Report of the Committee of Physics of the Royal Society; and from July 1843 to the end of 1845, in a double rectangular casing, which is thus described in a note from Captain SMYTHE of the Royal Artillery, Director of the St. Helena Observatory:—

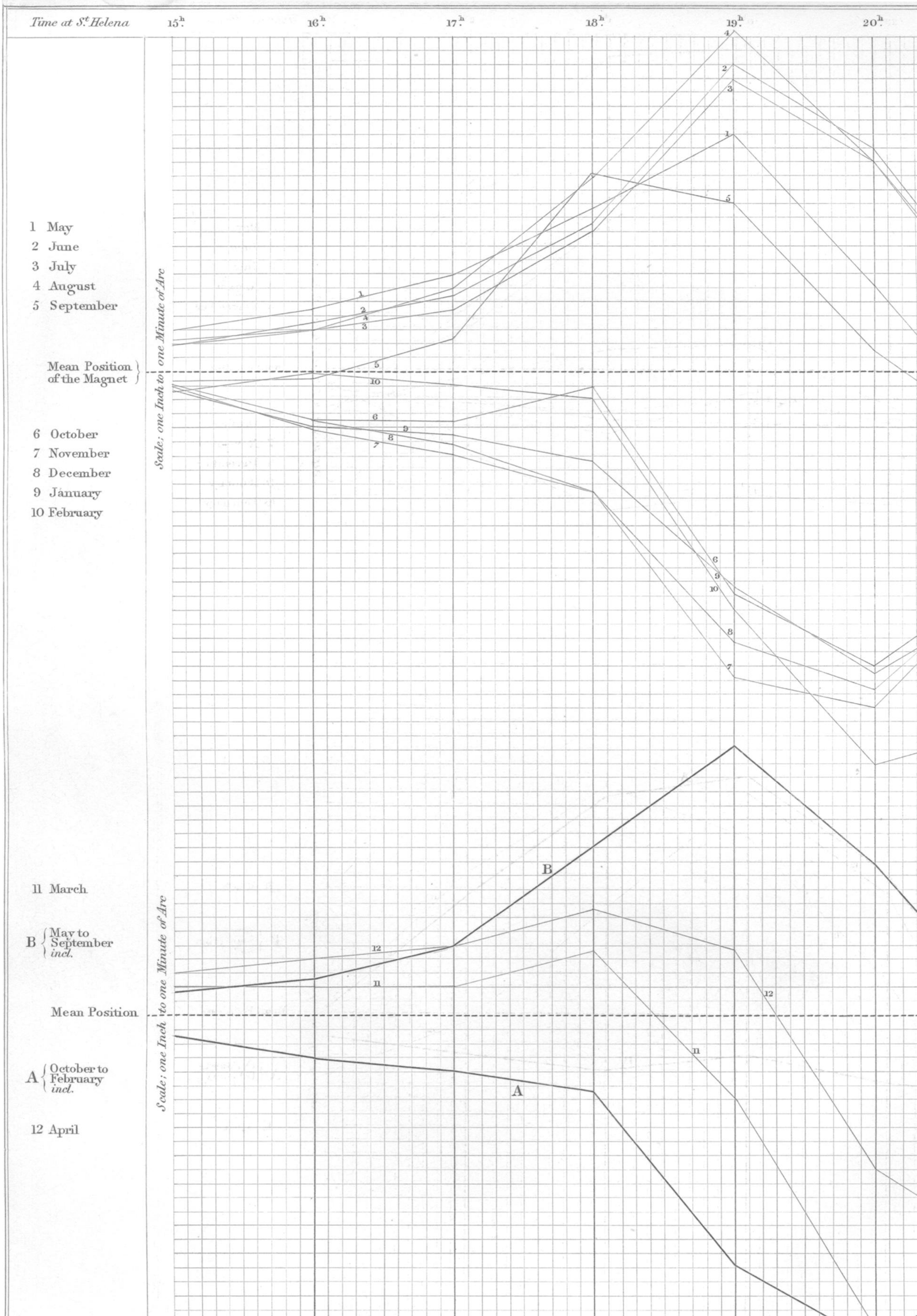
"A double rectangular box was made to inclose the magnet and replace the cylindrical one with glass top hitherto used. It is composed of two boxes made of mahogany, every way similar to each other, the outer one being about an inch in all its dimensions larger than the inner one. The boxes are divided in the middle, and the halves fit close when pushed together by being half sunk into each other where they join. The interior of the inner box, and the exterior of the outer, are covered

with gilt paper, and the boxes are kept firm in their place by screws which pass through the cross piece connecting the copper pillars, and resting upon the top of the outer box."

On a careful comparison of the observations before and after this change was made, no material difference is perceived which can be ascribed to currents of air produced by either form of the magnetometer box. The law of the diurnal variation is the same whether it be deduced from the observations of the first period of $2\frac{1}{2}$ years, or from the second period of the same duration. The extent of the arc which the magnet passes through in the twenty-four hours as a consequence of the diurnal variation, whether it be measured by the difference of the extreme east and west positions of the magnet, or by the sum of the fluctuations observed from hour to hour, is not the same in different months of the year, and is also found to differ to a small amount in the same months in different years: but these are obviously real differences depending probably on occasional inequalities in their magnetic causes, and appear equally in either series considered separately. The law of the variation in each month may generally be derived from the observations of any one year of the series, but its average amount is more correctly derived from a mean of several years. I have therefore employed in this communication the mean of the five years, but without burthening the paper by inserting the details of the separate series.

The diurnal variation which we obtain from the observations of the five years at St. Helena. shows that that station was well-chosen for the purpose of contributing to the solution of the problem in question: but the solution to which it conducts is of a very different character from that which was anticipated, and is one which seems not unlikely to assist materially in the eventual elucidation of the physical causes of the periodical variations. We have seen that in the northern portion of the globe the magnet moves to the east until seven or eight o'clock in the morning, and then returns to the west; it does so in every month of the year; the extent of the movement is greater in the summer than in the winter months, but the direction is always the same. So in the southern portion of the globe, the movement in the contrary direction is also constant throughout the year; it is greater when the sun is in the southern signs than when he is in the northern signs, but the direction is the same in all the months of the year; an extreme of westerly elongation is reached in every month about the hour of 8 A.M., as is an extreme of easterly elongation about the same hour in the opposite hemisphere. At St. Helena the well-marked peculiarity of the diurnal variation is, that during one-half of the year the movement of the north end of the magnet at the hours above referred to corresponds in direction with the movement which is taking place in the northern hemisphere, whilst in the other half of the year the direction corresponds with that which is taking place in the southern hemisphere. The opposite movements which take place simultaneously in every day of the year in the same meridians in the two hemispheres, do not by their mutual opposition neutralise each other and thus leave the magnet stationary. On the con-

DIURNAL VARIATION OF THE MAGNETIC DECL



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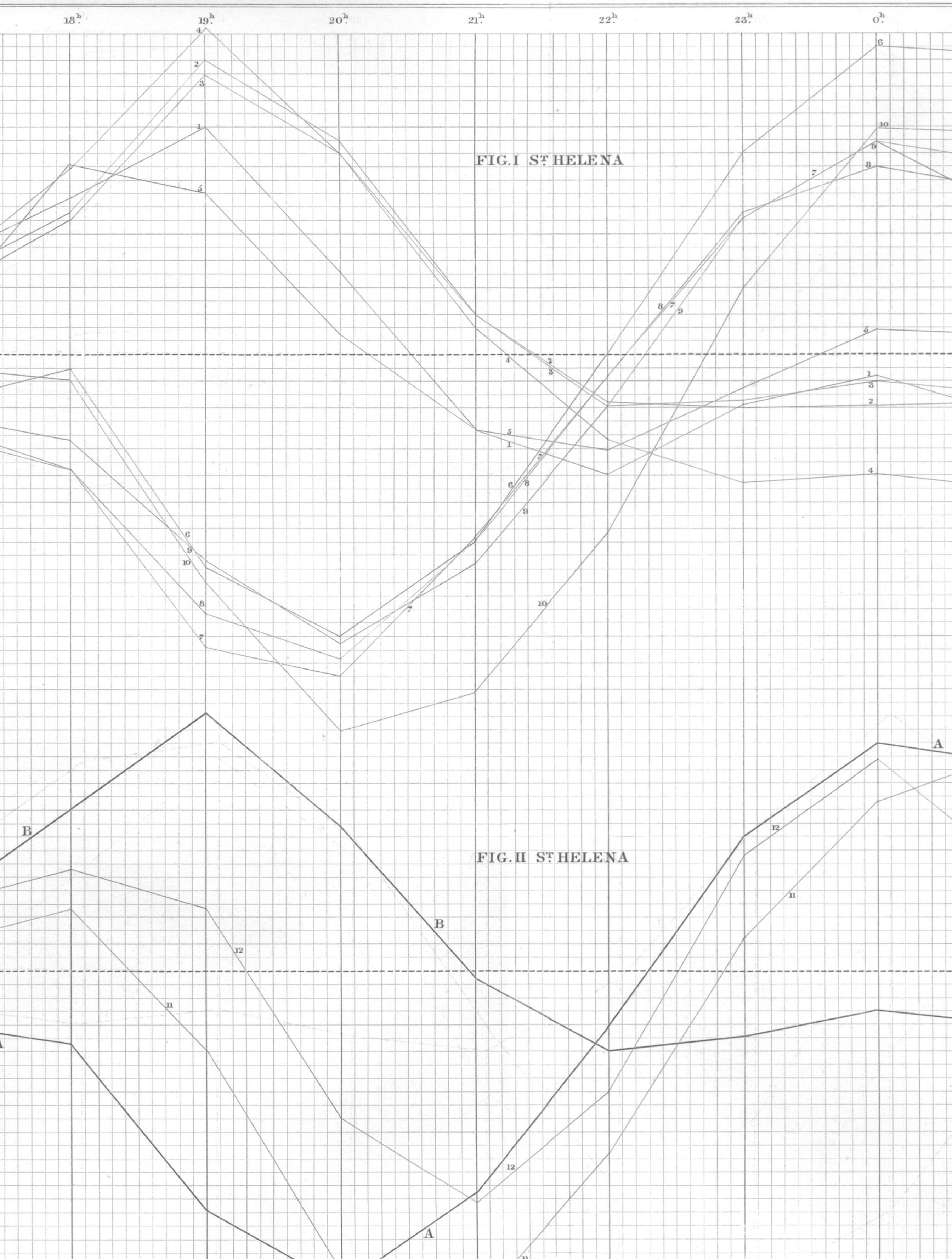
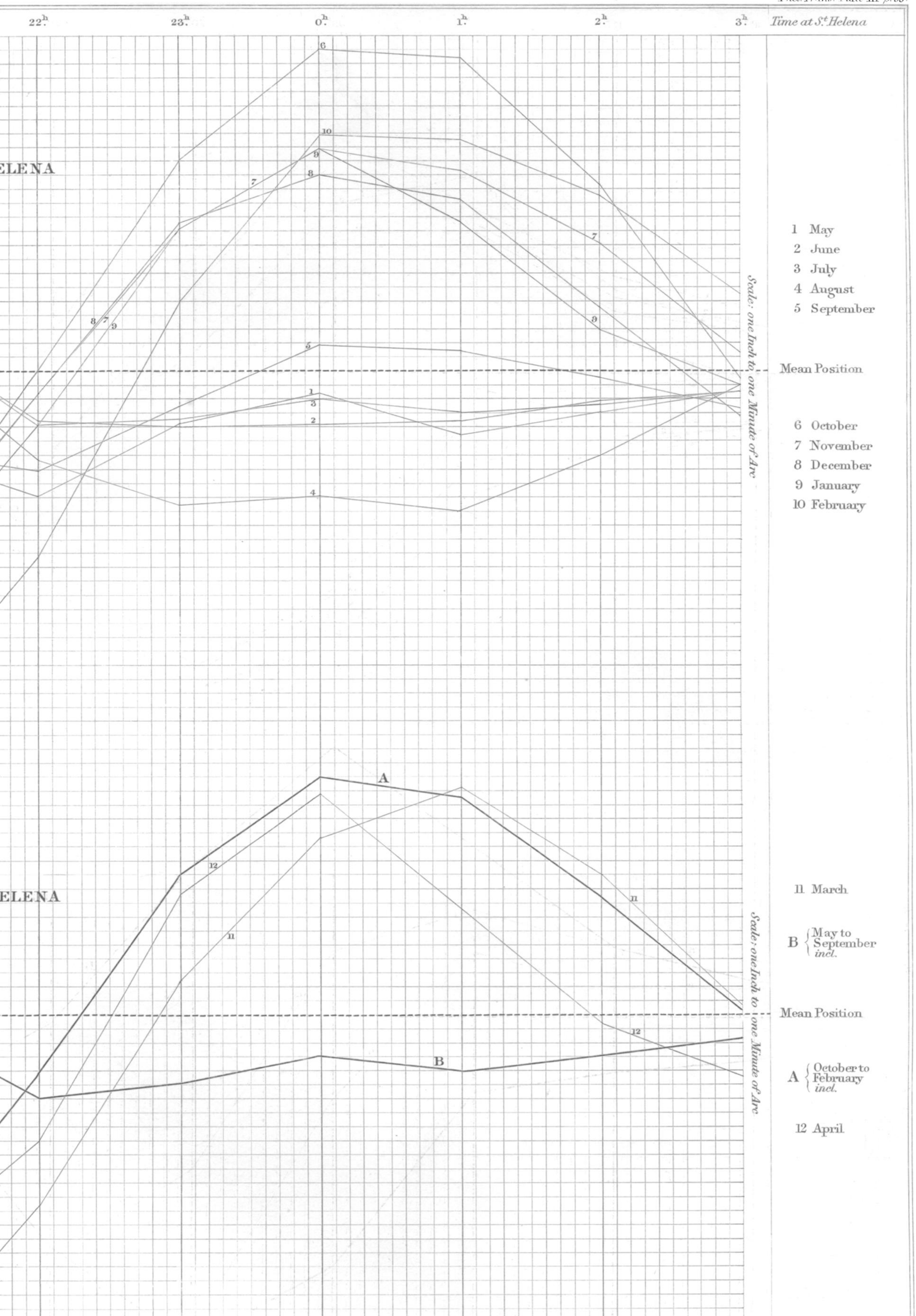
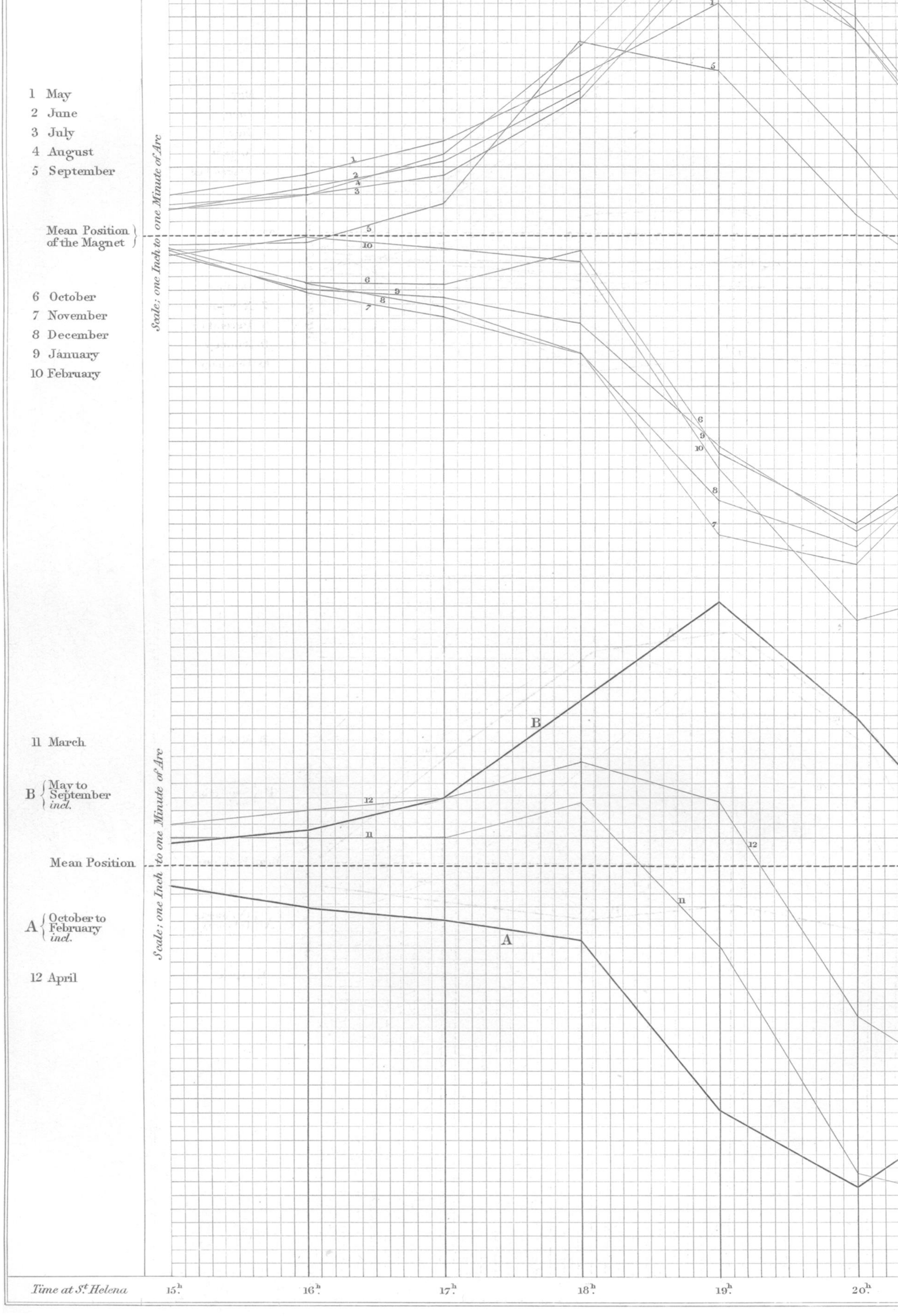
The NORTH end of the magnet moving towards th



The NORTH end of the magnet moving towards the EAST; | towards the WEST. ↓

Phil. Trans. Plate III. p. 55.





1 May
2 June
3 July
4 August
5 September
Mean Position of the Magnet
6 October
7 November
8 December
9 January
10 February
Scale; one Inch to one Minute of Arc
11 March
B May to September incl.
Mean Position
A October to February incl.
12 April
Scale; one Inch to one Minute of Arc
Time at St. Helena
15h.
16h.
17h.
18h.
19h.
20h.

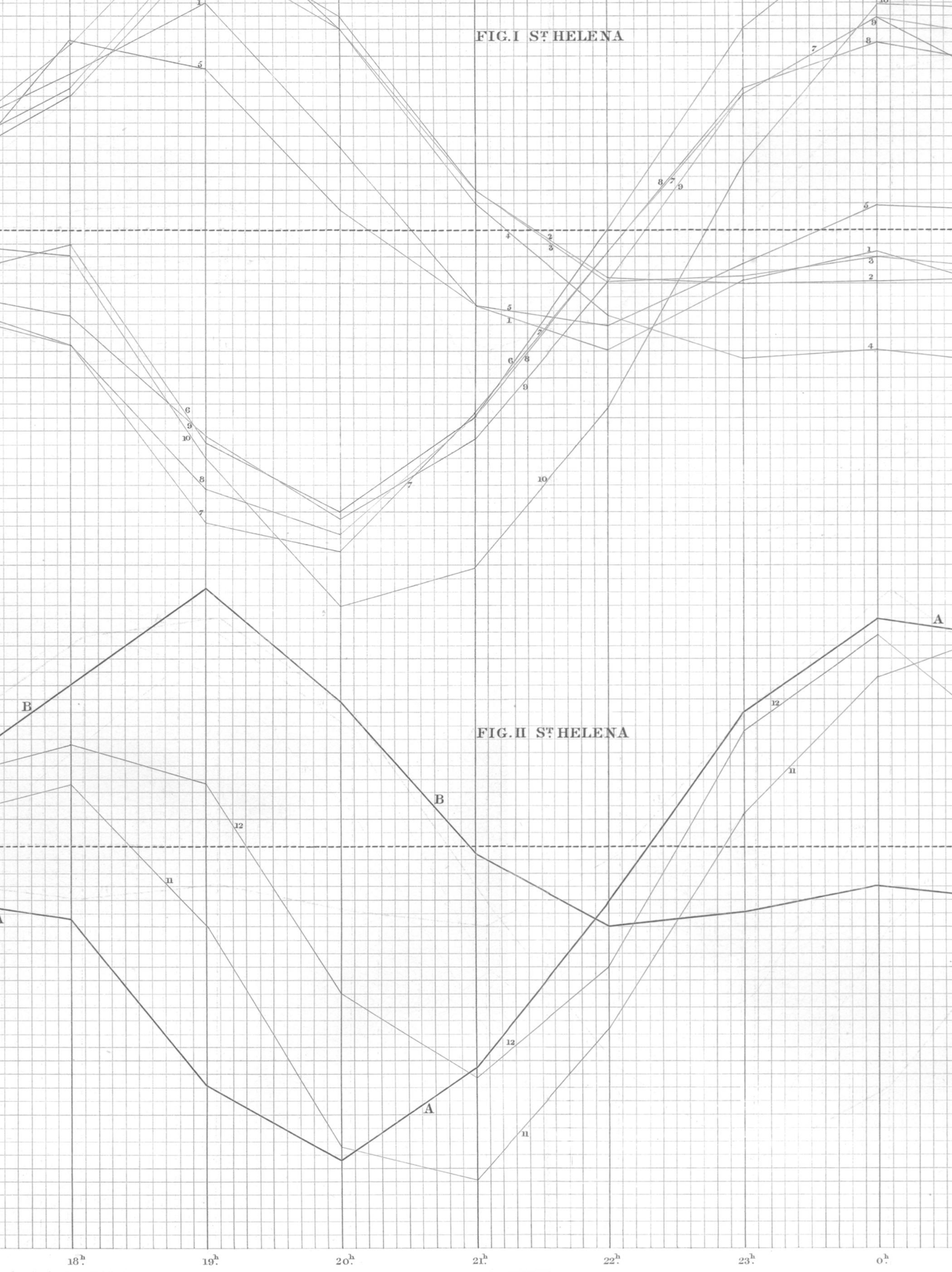
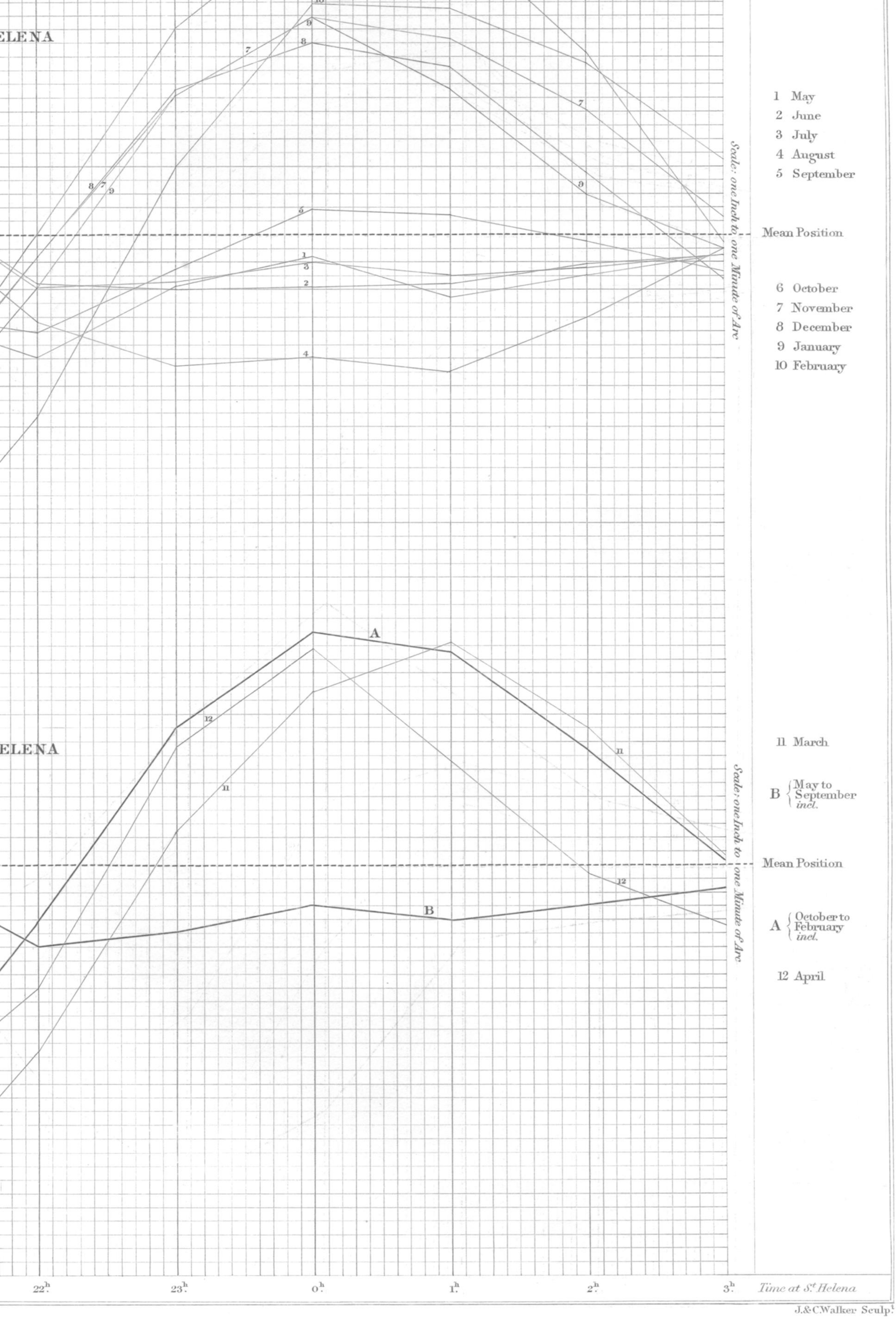


FIG. I ST. HELENA
FIG. II ST. HELENA
A
B
18.h
19.h
20.h
21.h
22.h
23.h
0.h



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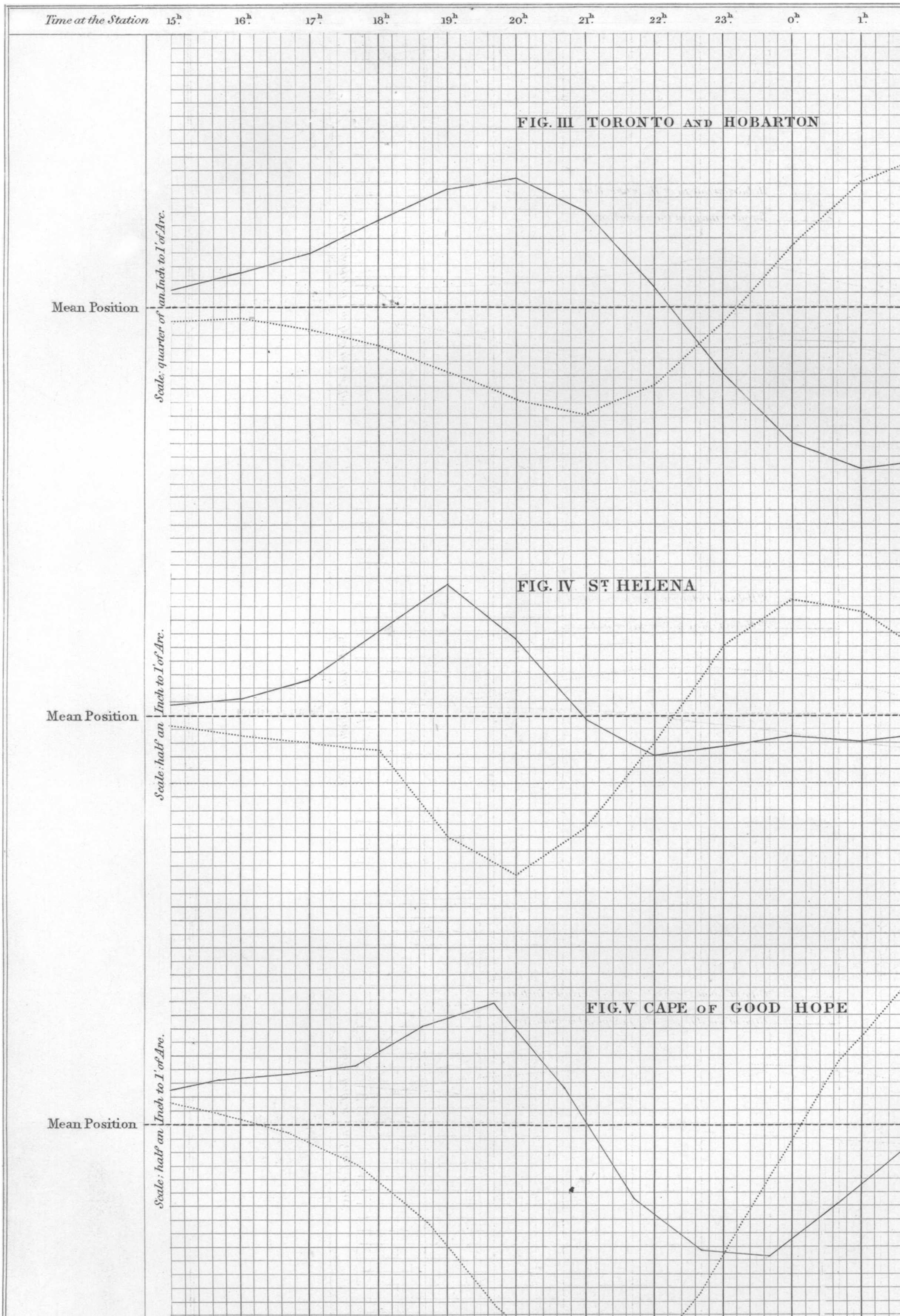

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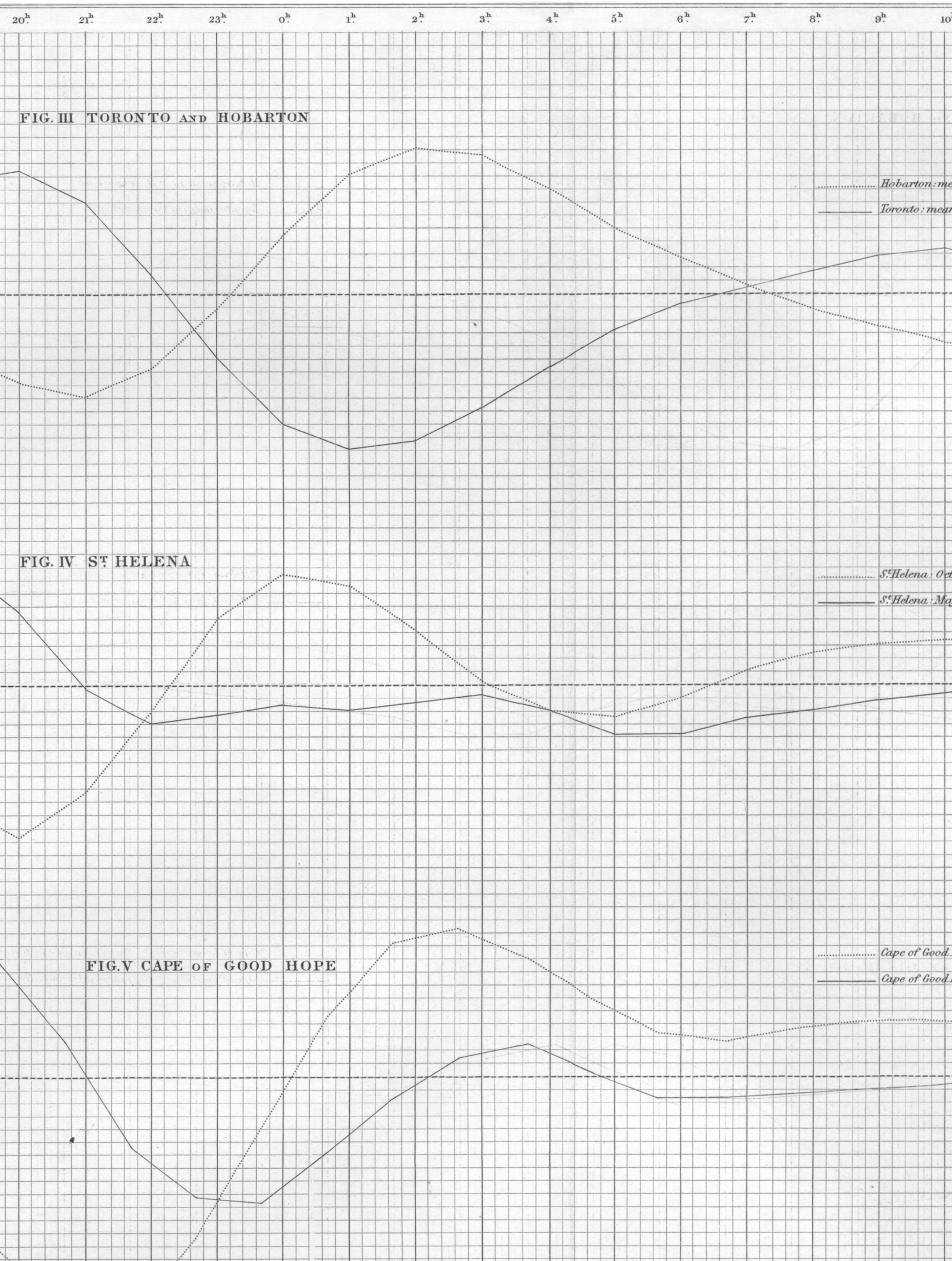
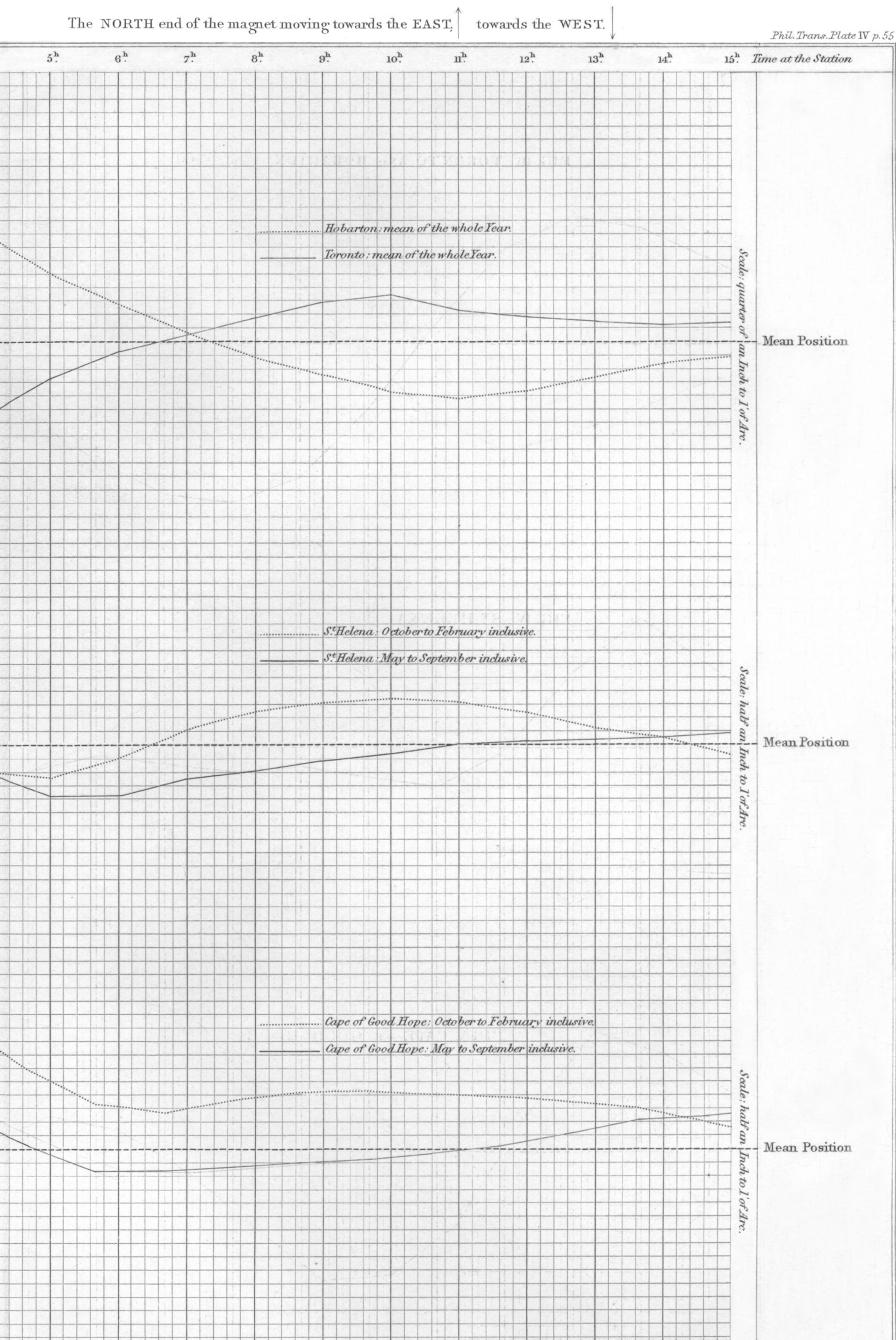
The NORTH end of the magnet moving towards th




The NORTH end of the magnet moving towards the EAST,
towards the WEST.
5.h 6.h 7.h 8.h 9.h 10.h 11.h 12.h 13.h 14.h 15.h
Time at the Station
Hobarton: mean of the whole Year.
Toronto: mean of the whole Year.
Scale: quarter of an Inch to 1' of Arc.
Mean Position
St. Helena: October to February inclusive.
St. Helena: May to September inclusive.
Scale: half an Inch to 1' of Arc.
Mean Position
Cape of Good Hope: October to February inclusive.
Cape of Good Hope: May to September inclusive.
Scale: half an Inch to 1' of Arc.
Mean Position

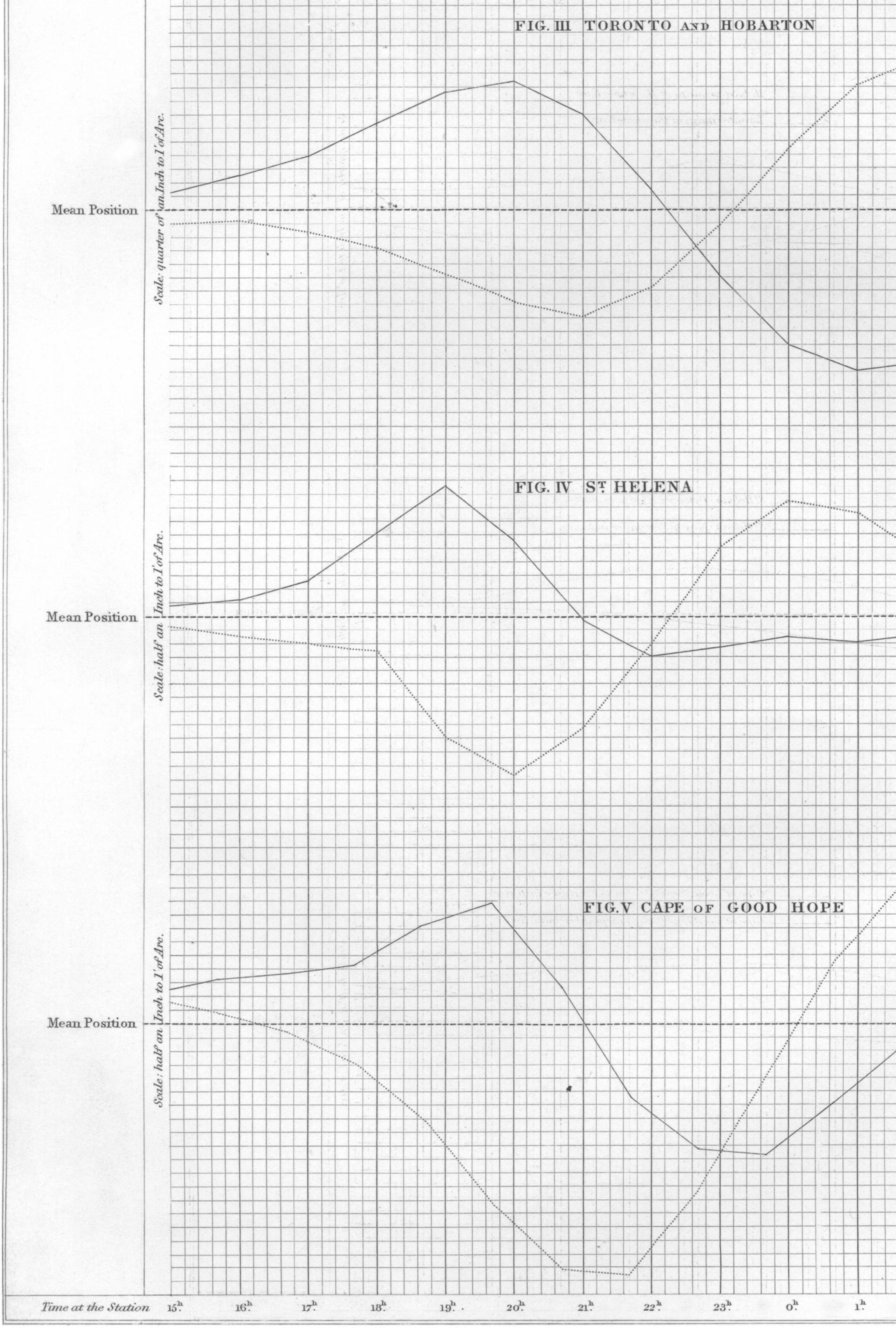


FIG. III TORONTO AND HOBARTON
Mean Position
Scale: quarter of an Inch to 1' of Arc.
FIG. IV St. HELENA
Mean Position
Scale: half an Inch to 1' of Arc.
FIG. V CAPE OF GOOD HOPE
Mean Position
Scale; half an Inch to 1' of Arc.
Time at the Station
15h.
16h.
17h.
18h.
19h.
20h.
21h.
22h.
23h.
0h.
1h.

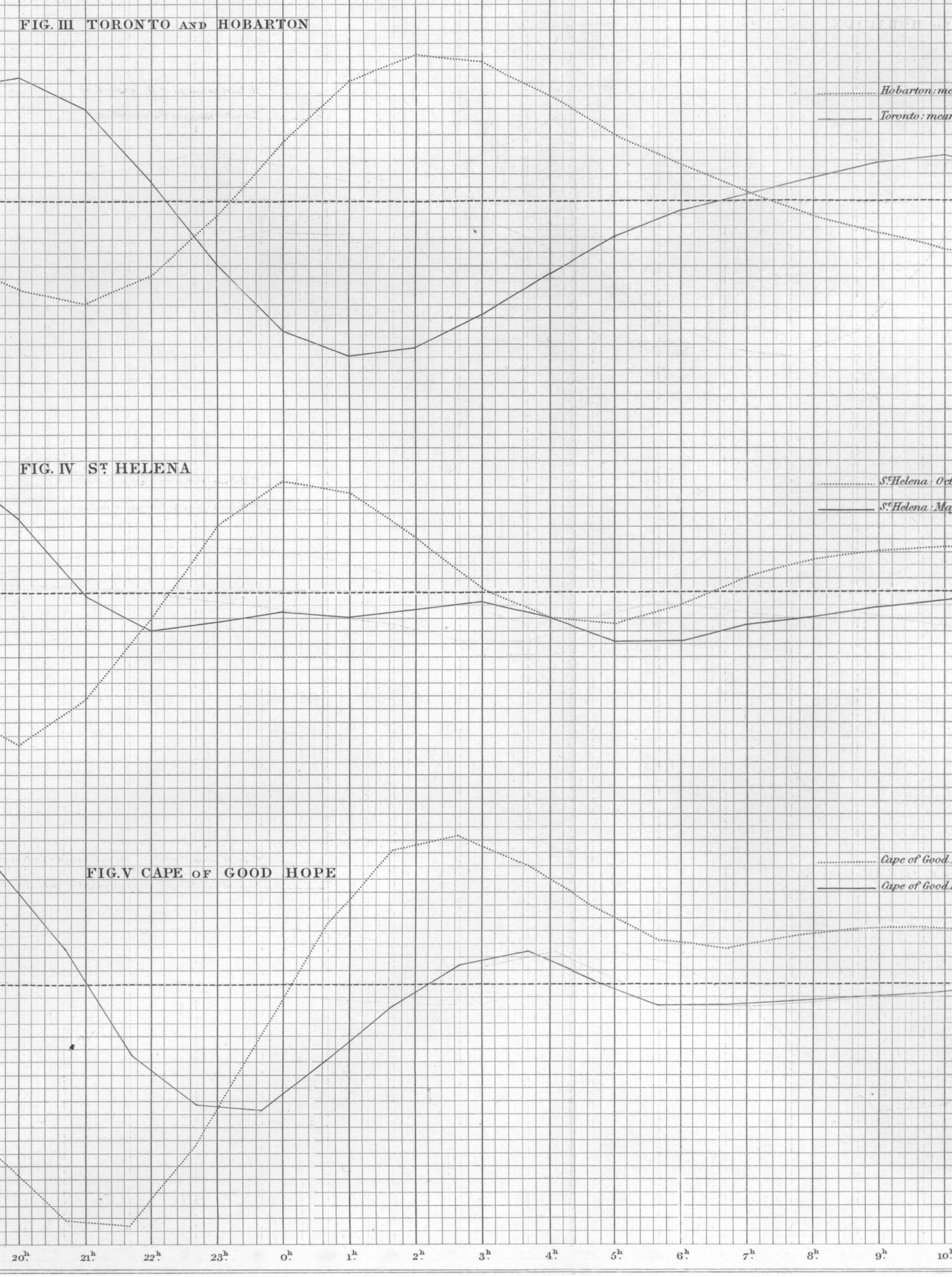
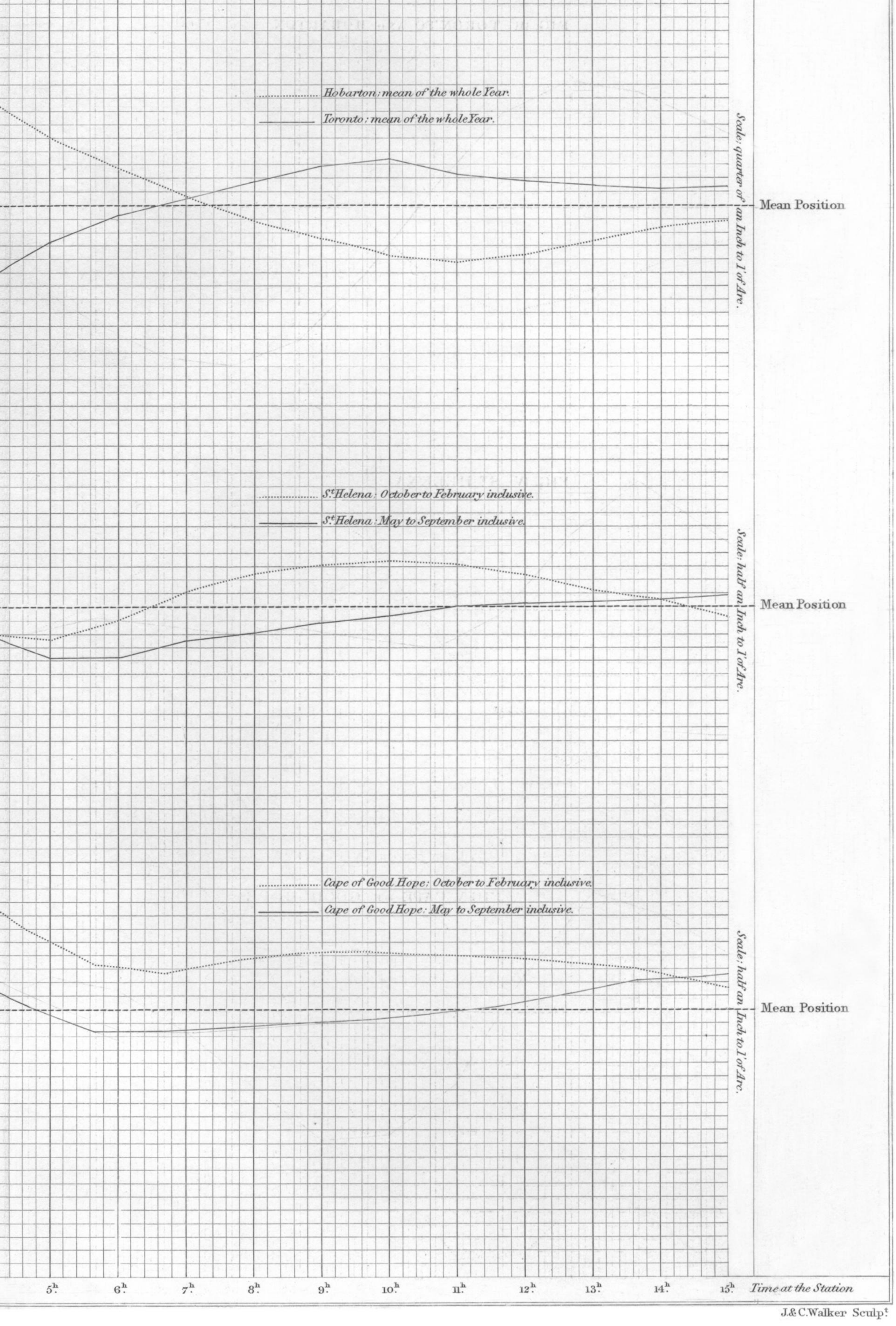


FIG. III TORONTO AND HOBARTON
Hobarton: me
Toronto: mean
FIG. IV St. HELENA
St. Helena: Oct
St. Helena: Ma
FIG. V CAPE OF GOOD HOPE
Cape of Good
Cape of Good
20h. 21h. 22h. 23h. 0h. 1h. 2h. 3h. 4h. 5h. 6h. 7h. 8h. 9h. 10h.



J. & C. Walker Sculp.t

trary, the diurnal variation at St. Helena partakes in, and possesses the characters of the phenomena of both hemispheres, but each predominates in its turn, prevailing separately and in opposite seasons. The passage from one order of the phenomena to the other takes place at or soon after the period of the equinoxes; in March and April, September and October, the diurnal variation at the hours referred to partakes, more or less on different days, of the characteristics of both seasons: but the months of May, June, July and August, on the one hand, and those of November, December, January and February, on the other, arrange themselves in wholly distinct categories; the north end of the magnet reaching its eastern extreme in the one case, and its western extreme in the other, nearly at the same hours; the extremes being moreover in both cases nearly equidistant from the mean position of the magnet in the respective months.

In Plate III. figs. 1 and 2 exhibit the projections of the diurnal variation at St. Helena from 3 A.M. to 3 P.M., in each month of the year, the projections representing the mean of five years of observations. In fig. 1, which contains all the months excepting March and April, September is seen to belong on the whole to May, June, July and August, although the influence of the opposite season is plainly visible at the hours of 18 and 19 (6 and 7 A.M.). October, on the other hand, must be classed with November, December, January and February, although an influence of opposite character is distinctly perceptible in the direction from 17^h to 18^h (5 to 6 A.M.)*. In fig. 2, the projections corresponding to the months when the sun has northern declination are collected into one darker line, as are those of the other five months when the sun has southern declination into another, for the purpose of exhibiting by comparison with the separate projections for March and April (which are the fainter lines), the degree to which the latter are intermediate. March and April have each both an eastern and a western elongation in the early morning hours; the eastern occurs one hour earlier than in May to September, and the western one hour later than in October to February: these peculiarities, both in regard to direction and to hours, are traceable without difficulty to the occasional alternation in those months of the influences of the opposite seasons.

Fig. 3. Plate IV. exhibits in the unbroken line the mean diurnal variation of the whole year at Toronto, and in the broken line the mean variation of the whole year at Hobarton in Van Diemen Island, showing the contrast which the *opposite hemispheres* present in this respect. In like manner the broken and unbroken lines in fig. 4 present in contrast with each other the diurnal variation of the *opposite seasons* at St. Helena. By the comparison of figs. 3 and 4, the general resemblance is shown

* The fact that October corresponds much more to November, December, January, and February than to May, June, July, and August is very decided; and is important to notice, because, although the sun passes to the south of the equator in September, he continues to the north of the parallel of St. Helena until the beginning of November. It is the sun's position in reference to the earth's equator, therefore, and not to the zenith of the place of observation, which marks the epoch of the change in the direction of the diurnal variation of the needle.

between the effect of the opposite hemispheres in the one case, and of the opposite seasons in the other, whilst at the same time the subordinate points of dissimilarity are equally conspicuous. It is not the object of this paper to enter on the discussion of minor points of difference, such as the non-agreement of the turning hours, which are somewhat earlier at St. Helena than at Toronto in the one case and at Hobarton in the other, and the check which appears to take place in the western elongation in May and September at St. Helena towards the hour of noon; but I may permit myself to notice, as a minor but apparently characteristic point of resemblance, the circumstance that the eastern elongation at the morning hour at Toronto, as well as in the corresponding season at St. Helena, always precedes by an hour the western elongation about the same period of the day at Hobarton and its corresponding season at St. Helena. This feature has a further tendency to connect a hemispherical peculiarity of daily occurrence throughout the year in each of the two hemispheres, with a periodical peculiarity at St. Helena conforming strictly to the alternation of the seasons.

The projections for Toronto and Hobarton in fig. 3 represent each a mean of two years of hourly observations; the scale on which they are drawn has been taken for convenience at half the magnitude of the scale on which the St. Helena projections in fig. 4 are drawn.

We have hitherto considered those portions of the diurnal variation at St. Helena which include the hours of the forenoon and of the first part of the afternoon. We have seen that from 3 A.M. to 3 P.M. the movement of the magnet is strikingly dissimilar, and is even opposite for a considerable portion of those hours, in the two solstitial periods of the year. A less marked but not less systematic difference takes place during the remaining hours, as is shown by the projections in fig. 4, which correspond respectively to the months from May to September, and from October to February. The diurnal variation at these hours, from May to September, consists in a small but continuous and steady motion of the north end of the magnet towards the east, commencing at 5 or 6 P.M., and continuing without interruption through the night until the following morning: whereas from October to February, the motion, which at first is in the same direction, is more considerable, and an inferior eastern extreme is reached about 9 or 10 P.M., to which there is nothing analogous at the other period of the year; a return then takes place towards the west (contrary to the direction in the opposite season), and is thenceforward continuous until the forenoon of the next day. In the night portion therefore of the diurnal curve as well as in that portion which has been more largely discussed, the horary variation at St. Helena does not disappear, but continues to exhibit a diversity at opposite seasons, in which an analogy may still be traced to the difference in the annual projections at Toronto and Hobarton at the same hours, shown in fig. 3. It should be noticed however that the correspondence which exists during the hours of the day between Toronto and those months at St. Helena which form the northern summer on the

one hand, and Hobarton and those months at St. Helena which form the southern summer, is not preserved in the night portion of the curve.

If the phenomena of the diurnal variation at St. Helena are characteristic of a station situated between the northern and southern magnetic hemispheres, partaking, although in opposite seasons, of those contrary features which separately prevail in the two hemispheres throughout the year, then we must regard the diurnal variation at the Cape of Good Hope, notwithstanding the remoteness of the situation of the Cape from the terrestrial equator and from the line of no dip, as supplying an additional illustration of the phenomena of an intermediate station. The projections in fig. 5, corresponding to the seasons May to September, and October to February, each representing also the mean of five years of hourly observation, bears a striking general resemblance to those of the preceding figure; the principal minor modifications also are such as may readily be imagined to be occasioned by the greater distance of the Cape from the dividing line. It will be remarked that the contrary movements at the opposite season of the year take place at the Cape of Good Hope as well as at St. Helena, although the sun is throughout the year to the north of the parallel of the Cape, and consequently is always north of its zenith.

Having named Singapore at the commencement of this paper, I may add that I have examined the manuscript observations of that station in 1841 and 1842, which are at the Royal Society: the observations appear to have been taken in those years at every second hour only, consequently the diurnal variation derivable from them is less complete than from an hourly record, but is quite sufficient to show that in general characters it corresponds with that of St. Helena and the Cape of Good Hope: the movement of the north end of the magnet in the months of May, June, July and August, is to the east until 7 or 8 A.M., followed by an immediate return to the west; and in November, December, January and February, to the west until 8 A.M., followed by an immediate return to the east: the last-named months have also an easterly extreme about 2 P.M., which has no similar or opposite feature in May, June, July and August.

From the facts here brought forward, it may be inferred that the line which has been supposed to exist by the eminent authorities referred to in the commencement of this paper, and which should be characterized by the absence of a diurnal variation of the declination, will not be found upon the globe.